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# Increasing Ecological Safety of Lead Production

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**Abstract.** Air pollution as a result of lead evaporation from the surface of melts is considered. Conditions for aerosol diffusion by convective and circulation flows are given. The method of analogy between processes of heat and mass transfer was used for the calculation of evaporation. A program set was developed and new data were obtained on the amount of lead transferring into the air from the melts open surfaces and during transportation in ladles with considering of the cooling

## 1. Introduction

Lead production, including smelting of rough lead and its further refining, is accompanied by environmental pollution with various substances. Among these substances, highly toxic lead compounds predominate [1]. Lead plants emissions are of serious hazard to the environment. They cause air pollution and consequently soil and water pollution.

The source of lead in the working zone air is the open surfaces of the melts. In melting shops technological processes are carried out at the temperature of 800-1350 degrees Celsius, and the lead goes into the air mainly in the form of aerosols due to evaporation [2]. Combined ventilation is now used, which consist of local and general ventilation. Local ventilation removes harmful substances from the melt overflow nodes, and general ventilation provides aeration. A significant amount of aerosols comes from ladles with melts during their transportation between the melting units.

Lead refining is performed at temperatures of 330 – 900 degrees Celsius. Lead transfers in air as a result of dust formation when slug crusts overloading, melt stirring and ladles transporting. Using of local ventilation is difficult due to the conditions of refining. Ventilation of refining workshops is performed with general ventilation. This method of ventilation is not effective enough in spite of ventilation rate.

The air from local ventilation systems is cleaned in bag filters and electrical precipitators, and then released into the atmosphere. The most dangerous are the low sources of lead emissions, that is, aeration femerells. Femerell emissions are poorly dispersed and cause pollution of the surface layer of the atmosphere. It complicates the organization of supply systems air intake and restrict the aeration use.

Reduction of environmental pollution can be achieved on the basis of complex technical solutions including technical measures and improvement of the ventilation for emissions reducing and the replacement of low emission sources.



## 2. Experimental

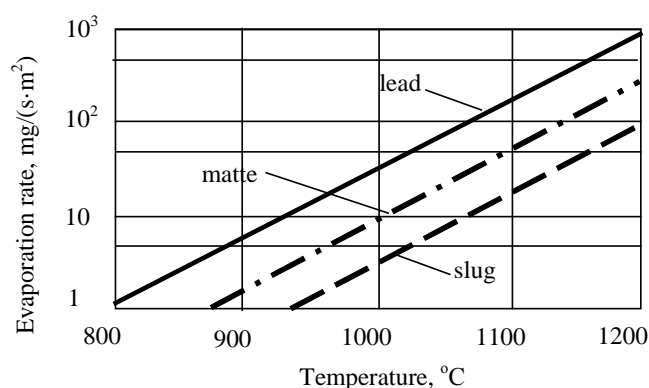
The dynamics of the melt transport in the ladle was estimated on the base of technological process timing in the melting shop, Ust-Kamenogorsk lead-zinc plant [1]. Evaporation and cooling of melts evaluated using methods of mathematical and computer modeling [5, 6].

Data on the amount of dust in air and the lead content in this dust were obtained from in-place tests at different stages of refining [2]. Sampling for dust and lead in convective flows over refining tanks was carried out by aspiration-weight method. The content of dust and lead in the samples was determined by the polarographic method (sensitivity of the method - 0.5 mg / l, error 10%).

Possible pollution of atmospheric air, water and soil in the emission dispersion zone estimated on the basis of the emission dispersion calculation using the Methodology for calculating the concentrations of harmful substances contained in the enterprises emissions.

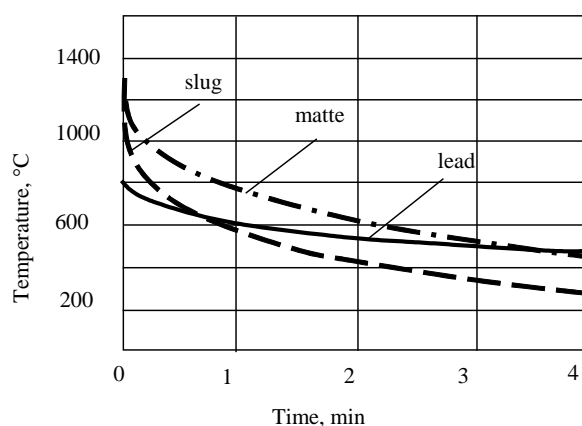
## 3. Results and discussion

Using the method of analogy of the processes of heat and mass transfer and the basis of the molecular-kinetic theory [7, 8], the authors developed a method for calculating the evaporation of metals from the melts surface [9]. The obtained dependences allow determining the intensity of lead vapor release taking into account the temperature and percentage of lead in the melt. Figure 1 shows the results of calculations for the main melts of lead production, namely, matte, slag and rough lead with lead content of 12%, 3% and 98%, respectively. As shown in the figure, the intensity of evaporation depends substantially on the temperature and the melt type.



**Figure 1.** Evaporation rate of lead.

During transportation of melt or its settling, the melt surface cools and the evaporation intensity decreases. To assess the dynamics of these processes, regularities of nonstationary heat transfer for a sphere [10, 11], equivalent to the ladle in volume, were used in the range of the numbers  $Bi = 30 \dots 300$  and  $Fo = 0 \dots 0.2$ , with considering the dependence of the thermophysical characteristics of melts from the temperature. The temperature change of the melts surface in the ladle with cooling is shown in Fig. 2. We note here that the cooling of the surface occurs rather quickly. In a minute the temperature of slag became 0.35 (fraction of the original value), of matte - 0.62; of lead - 0.75. Thus the nature of the surface temperature decrease depends on the thermophysical properties of the melts.



**Figure 2.** Cooling of the melt surface in ladles.

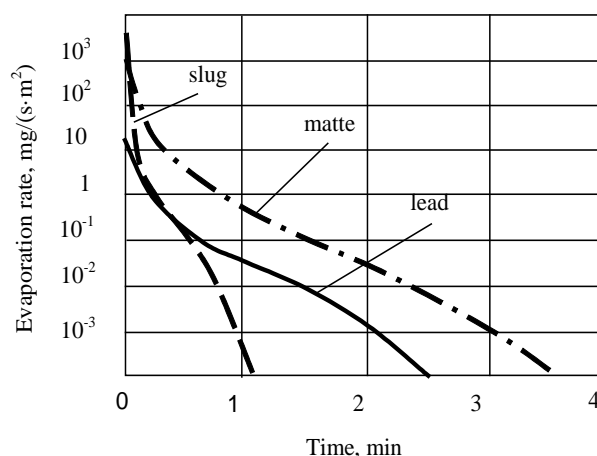
The data presented (Figures 1 and 2) make it possible to estimate the dynamics of the lead evaporation processes during ladles transportation and settling of melts (Fig. 3). The maximum intensity of evaporation corresponds to the moment when the ladle is filled with matte because of a high initial temperature. For slag the initial intensity of evaporation is less due to the smaller content of lead. The lowest intensity of evaporation is at the moment of casting the ladle with rough lead, but the decrease in the intensity of evaporation occurs slowly. For all melts, formation of lead aerosols due to evaporation depends on the residence time of ladle out of the shelter.

In light of the foregoing, an addition was made to the technological regulations on the need for the sludge to be placed under the shelters of local exhaust ventilation for at least one minute. It allows reducing the transferring of lead to the air from 36 to 1 mg/s.

Estimation of air pollution during refining was obtained on the basis of full-scale studies performed jointly with the Central Research Institute for the Prevention of Pneumoconiosis (Ekaterinburg) in the refining shop of the Ust-Kamenogorsk lead-zinc plant (Kazakhstan). Table 1 shows the amount of incoming dust and the lead content in different stages of the technological process.

**Table 1.** Lead emission by stages of the refining process

Technological operation	Max. melt temperature, °C	Lead emission from one pot, mg/s	Lead emission from 1m <sup>2</sup> surface, mg/s
Ladling out of lead	800	23.3	2.23
Dressing:			
- coarse dressing of lead	500	1.3	0.124
- fine dressing of lead	600	10.0	0.952
I alkaline refining	600	4.8	0.457
Desulverization:			
- mixing	540	12.5	1.19
- settling	330	1.2	0.124
- foam removal	330	5.0	0.476
Tellurium removal:			
- sodium blending	380	5.0	0.476
- settling	380	0.5	0.048
Bismuth removal			
- mixing	380	6.5	0.619
- dross removal	380	0.7	0.067
II alkaline refining			
- nitrate loading	550	16.0	1.52
Fusion removal	380	0.4	0.038



**Figure 3.** Dynamics of lead evaporation from ladles

Taking into account the technological arrangements in the smelting shop, it is possible to reduce the required air exchange to the air volume removed by local suction. This excludes a necessity for additional suction from the upper zone [9]. In order to reduce the contamination of the working area by recirculation flows, the supply air must be supplied directly to the working zone by panel-type air diffusers. At that, lead concentrations in the working area tends to the maximum permissible values (MPCs). It also eliminates the need to remove contaminated air through the femerell.

In order to achieve the maximum permissible concentration in the working area, air exchange must be ensured in the flow volume in the convective stream above the melting pot at the level of ceiling, that is, in the absence of recirculation. Minimization of air exchange in the refining shop is achieved on the basis of an analysis of the operating conditions of the melting pots. Draught can only be realized over melting pots operating in an intensive mode [12]. Removal of air is provided from the upper zone by means of an exhaust manifold with receiving openings equipped with valves with remote control. All the exhaust air is sent for cleaning to the gas cleaning department. Thus the polluted air emission through the femerell is excluded.

The environmental effect of the proposed activities is as follows: holding the ladles with melts under covering before transportation, exclusion of the release of unpurified air through the femerells, reducing the amount of air being removed.

At present, there are no MPC standards concerning atmospheric surface layer air of industrial sites. The recommendations of the Code of Regulations SP 60.13330.2012 "Heating, ventilation, air conditioning" is used as a criterion of air quality. According to the rules, use of unpurified air for supply air systems and aeration of industrial buildings can be possible, if the concentration of harmful substances does not exceed 0.3 MPC (working area). Since the value of MPC (working area) for lead is 0.01 mg / m<sup>3</sup>, the concentration of lead in the surface layer should not exceed 0.003 mg / m<sup>3</sup>. Calculation of emission dispersion revealed that the increase in lead concentration during femerell emissions is 0.0053 mg / m<sup>3</sup> in the smelting shop and 0.027 mg / m<sup>3</sup> in the refining shop, which exceeds the standard by 1.8 times in the first case, and 9 times in the second case.

It is possible to achieve a corresponding decrease in lead concentrations in the atmospheric surface layer on account of preventing the emission through the femerell, which gives the lead release of 1.14 tons per year. Replacement of the aeration femerell in the refining shop makes it possible to eliminate lead emissions in the amount of 3.3 tons / year.

As a result of air pollution in the lead production, pollution of soils and water occurs. This is due to the precipitation of lead aerosols into the soil, and then in the water with rain effluent. According to the data on the fertilizers removal from agricultural, the removal of hazards varies widely and depends on climatic conditions, the type and texture of the soil, and ranges from 0.1 to 30%. Thus, some of the

lead aerosols are found in nearby reservoir. For example, up to 4 tons of lead dust is annually transferred in the reservoirs located near the Ust-Kamenogorsk lead-zinc plant through the fume of the smelting and refining shops.

The introduction of the proposed measures almost completely excludes the influence of workshop ventilation emissions on reservoirs and soil, as the release of polluted air without cleaning is prevented.

#### 4. Conclusion

1. It has been established that rooms in the production of rough lead air contamination of production rooms occurs mainly as a result of evaporation from the melts surface during transportation in ladles. As to the refining process, contamination occurs as a result of dust formation under intensive operating conditions of process equipment.

2. The results of calculating the melts surface cooling show that the nature of the surface temperature decrease depends on the thermophysical properties of the melts and the lead content. Cooling of the melt surface leads to a decrease in the intensity of evaporation, therefore, when estimating air pollution, the residence time of ladle out of the shelter should be taken into account. The time increase allows reducing the transferring of lead aerosols by a factor of ten and higher.

3. In the smelting shop, the exposure of the ladles under the shelter allows to reduce the air volume to the value of removed air by local exhausts. It will enable to eliminate the emission through the fume. Removal of contaminated air should be carried out by local exhaust ventilation systems with subsequent purification.

4. Minimization of air exchange in the refining shop is achieved using an analysis of the operation mode of melting pots. Draught can only be realized over melting pots operating in an intensive mode. Removal of polluted air should be carried out by a system of general ventilation with the following cleaning.

5. Elimination of emission from fumes allows obtaining an ecological effect by reducing the pollution of the industrial site air and eliminating the influence of workshops on the water and soil of the surrounding area.

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